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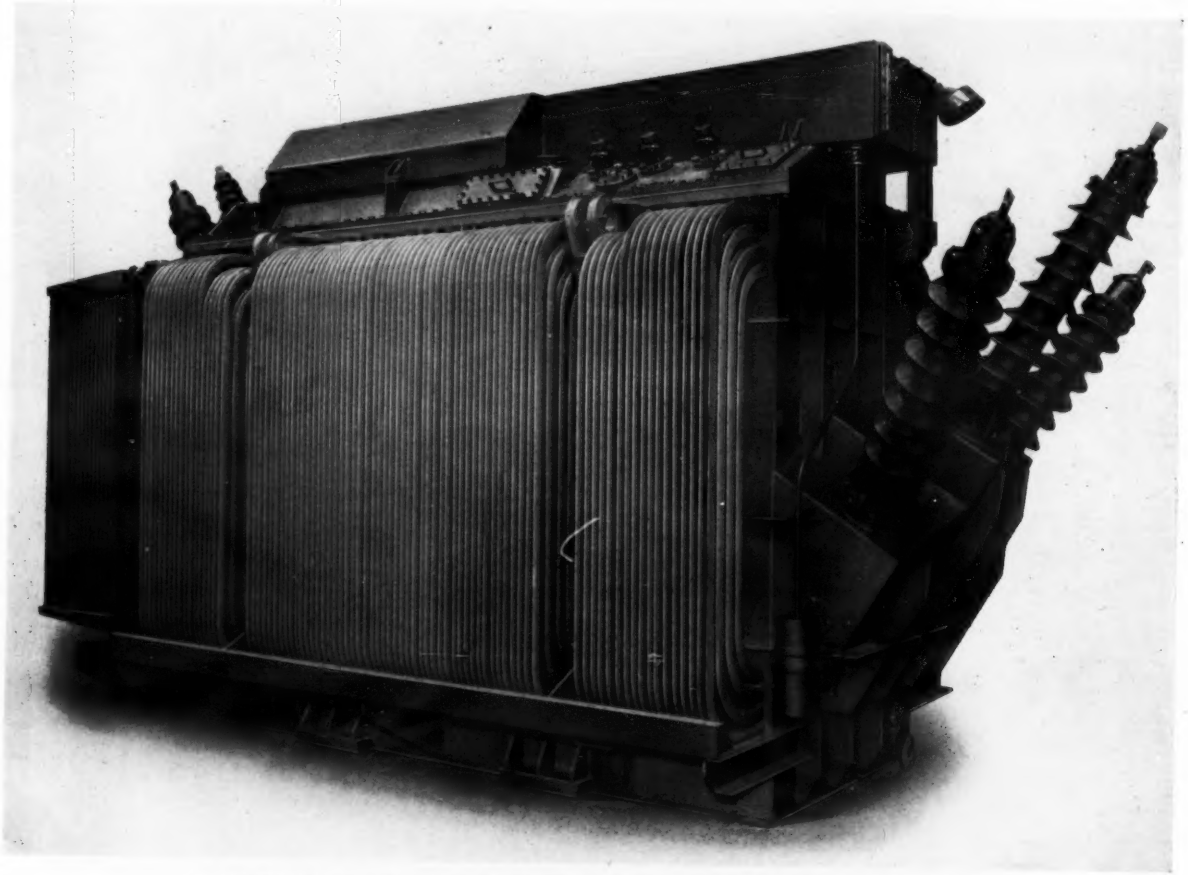

A 10,000 kVA Transformer supplied to the U.S.S.R. specially designed to enable transport by rail in a completely erected state.

The English Electric Journal

Vol X. No. 9 JULY, 1944. One Shilling

Multi-Winding Transformers.

By R. M. CHARLEY, M.C., B.Sc., M.I.E.E., Mem.A.I.E.E.

The elementary conception of a transformer is one having two windings for transforming voltage and current in one winding into voltage and current in the other winding, usually at different values of voltage and current; these two windings may be "double-wound" or "auto-connected." As an extension to this simple application, transformers are frequently built with three windings and occasionally with four windings, two of these being sometimes "auto-connected." There are two main applications of the additional winding, (*a*) to perform some auxiliary function, such as the compensation for conditions resulting from certain system and transformer arrangements, or (*b*) to provide electrical connection between three or four systems, all of which may operate at different voltages.

The common example of (*a*) is the provision of a tertiary winding on transformers that are Star/Star connected, this auxiliary winding being connected in Delta. This feature is necessary in order to prevent abnormal third-harmonic voltages being produced in the transformer and system, which might otherwise cause damage and interference with telephone or telegraph services, and also to stabilise the neutrals of the supply systems and to ensure the effective operation of protective equipment. Particular care must be taken in the design of such a transformer; consideration must be given to the earthing conditions of the systems and the protective equipment provided. Such factors have an important bearing on the equivalent capacity of the tertiary winding and the reactance between it and the two main windings; generally speaking, this winding is designed to have an equivalent capacity of about one-third that of each main winding. Fig. 1 shows a transformer for this service. The tertiary winding is usually located next to the core, the L.V. winding coming next, the H.V. winding being on the outside. The voltage of the tertiary winding is chosen at a value that will give the best possible winding from mechanical and thermal considerations. Sometimes this winding is brought out to terminals or a cable box in order to provide a small local supply at, say, 415 volts; if the voltage chosen for the tertiary winding is some other value, for the reason given above, say, 1,500 volts, a small auxiliary transformer is used to transform the tertiary voltage of 1,500 volts to the local supply pressure of 415 volts.

A further application of (*a*), not found in Great Britain but very common in the wide Continents, is the provision of a third winding on a main transformer in order to supply power to a synchronous condenser. This feature is made necessary by the great length of transmission line which creates a problem of voltage and power-factor control and system stability. A typical example of this application is where a long line, perhaps from a hydro-electric station, and operating at, say, 220 kV joins a more local system operating at, say, 110 kV; at this point a synchronous condenser is necessary, and supply must be given to it at, say, 11 kV from either the 220 kV or 110 kV systems. The load of the synchronous condenser is at practically zero power-factor leading; if the supply is given through a separate two-winding transformer, this fact has no influence in reducing the equivalent transformer size, whereas, if the supply is provided from an auxiliary winding on the main transformer a valuable economy is achieved. The following calculation will illustrate this point.

Suppose the load on the 110 kV system is 50,000 kVA at 0.8 P.F. lagging, and the synchronous condenser load is 30,000 kVA at zero P.F. leading, the resulting demand from the 220 kV system is 40,000 kVA at Unity P.F.

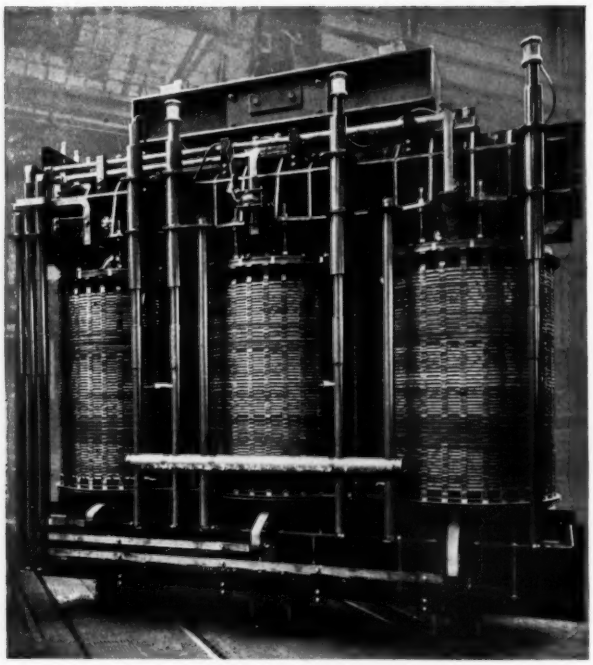

Fig. 1.—40,000 kVA Three-phase Transformer, 66/33 kV—Star/Star connected, 1,830-volt Delta connected Tertiary Winding.

These conditions are shown vectorially in Fig. 2.

The 220 kV winding must be made suitable for a capacity of 50,000 kVA as for the 110 kV winding, to allow for the condition when the synchronous condenser is not running. The equivalent capacity of transformers to meet these conditions with two two-winding transformers, alternatively, a three-winding transformer, is indicated in the following calculation :—

	Two two-winding Transformers. kVA	kVA	Three-winding Transformer. kVA
220 kV winding ...	50,000		50,000
110 kV winding ...	50,000		50,000
110 kV winding ...		30,000	—
11 kV winding ...		30,000	30,000
	100,000	60,000	130,000
Equivalent Capacity on basis of two-windings ...	160,000 ÷ 2 = 80,000		÷ 2 = 65,000

The three-winding transformer not only shows an economy on account of its smaller equivalent kVA but the unit cost per kVA will be lower than for the two two-winding transformers, each of which has a smaller equivalent capacity. There would be further saving from the fact that the three-winding alternative would require less switchgear. It is probable that the transformer for such a system connection would be Star/Star connected, in fact it might even be auto-connected, in which case a Delta connected tertiary winding would be necessary ; if this winding is used to supply the synchronous condenser, it is possible to use tappings on one corner of the Delta for the purpose of starting the synchronous condenser.

The English Electric Company recently built an interesting example of such a transformer for service in New Zealand. It comprises a 33,000 kVA bank of single-phase units, the main windings being arranged in auto-connection to couple together two systems operating at 110 kV and 66 kV respectively. The tertiary winding has a capacity of 20,000 kVA ; it is connected in Delta and is used to supply a synchronous condenser at 11 kV. Fig. 3 shows the general arrangement of one of these single-phase units. The transformer is provided with radiators for the dissipation of the losses by natural cooling.

The usual application of a multi-

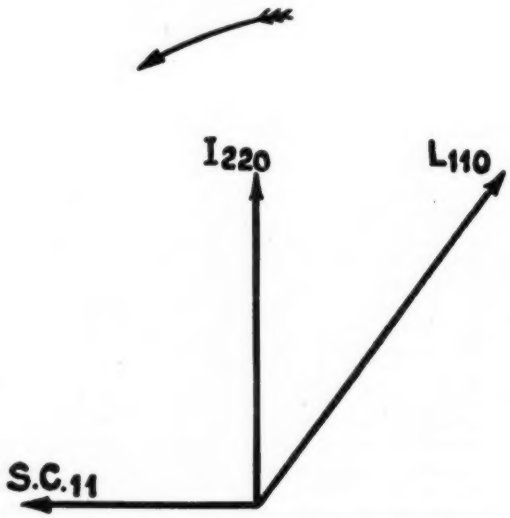

Fig. 2.—L. 110—110 kV Load, 50,000 kVA at 0.8 p.f. lagging.
S.C. 11—Synchronous Condenser Load 30,000 kVA at Zero p.f. Leading.
I. 220—Resultant Input to 220 kV Winding, 40,000 kVA at Unity p.f.

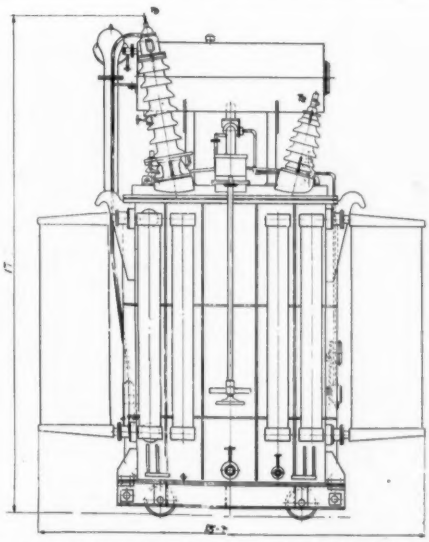

Fig. 3.—Single-phase Transformer for 33,000 kVA Three-phase Bank, 110/66 kV—Star-Auto connected, 11 kV Delta connected Tertiary Winding for supplying 20,000 kVA Synchronous Condenser.

winding transformer is in cases where three or more systems are to be connected together; these usually operating at different voltages and power flow being possible in various directions. A number of such transformers have been, or are being, built in this Country.

The Company has built a number of 10,000 kVA transformers with three windings for operating voltages of 110 kV, 38.5 kV, and 6.6 kV respectively. The 110 kV and 38.5 kV windings are Star connected and the 6.6 kV winding is Delta connected. Tappings connected to tapping-switches for off-circuit changing are provided on the two higher voltage windings, each giving plus and minus $2\frac{1}{2}$ per cent. and 5 per cent. variation about the normal voltage, respectively; these are all full capacity tappings. Each winding is designed for the full capacity of 10,000 kVA and they may be loaded in any combination provided that no winding is loaded in excess of 10,000 kVA. The impedance between the three windings, on the basis of a load of 10,000 kVA, is as follows :—

110 kV to 6.6 kV	...	...	10.5%
110 kV to 38.5 kV	...	...	7.0%
38.5 kV to 6.6 kV	...	...	6.0%

The 38.5 kV winding comprises a column of disc coils, each coil consisting of a number of single turns of a single rectangular wire, the whole column being wound as a single continuous winding; the tappings are taken only from outside joints between coils; this winding is located next to the core. The 6.6 kV winding is formed as a single-layer disc-spiral coil, the conductor being a number of rectangular wires in parallel; it is located between the 38.5 kV winding and the 110 kV winding. The latter is built up of a column of double-section disc-coils, each disc having a number of turns of a single rectangular wire; the tappings are taken from outside joints between coils only. The arrangement of these three windings is clearly seen in Fig. 4. It will be noticed that in the middle of

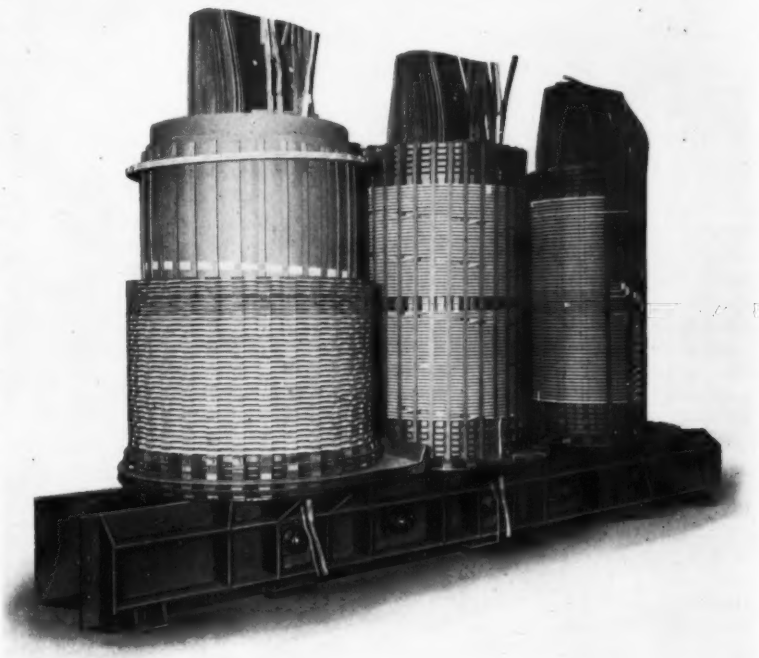

Fig. 4.—Arrangement of Windings of Transformer shown in Fig. 5.

Left-hand limb - -	*110 kV.*
Middle limb - - -	*6.6 kV.*
Right-hand limb - -	*38.5 kV.*

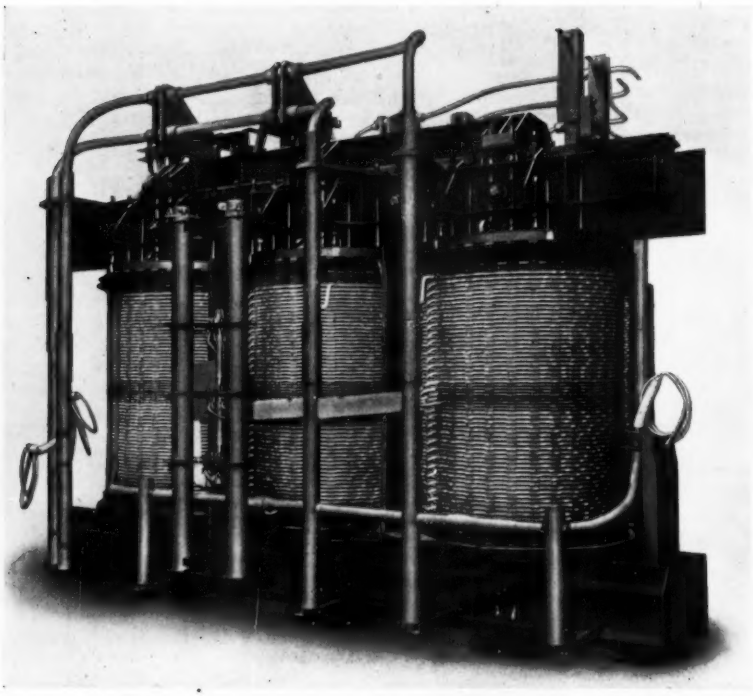

Fig. 5—10,000 kVA Three-phase Transformer. Three windings each of 10,000 kVA capacity, 110/38.5/6.6 kV—Star/Star/Delta connected.

the L.V. winding on the centre limb there is a gap which is opposite the tapping coils in the 110 kV and 38.5 kV windings. This is a very valuable feature in producing the greatest possible measure of symmetry between all three windings on any tapping connection, thus ensuring that, under short-circuit conditions, the resolved vertical mechanical force is kept well within the limit of the ultimate structure strength of the windings. Fig. 5 shows the completely assembled core and windings with the 110 kV tapping-switch.

An interesting feature of these transformers is that they are arranged for transportability on railway trucks with all fittings (except the rollers) in position, so that they are ready for immediate service. In spite of this restriction and also the fact that the transformer has three windings each of 10,000 kVA capacity, provision is made for dissipating the losses by natural radiation; the maximum total loss is 130 kW. The radiating surface comprises elliptical tubes welded into two sides of the tank and a bank of detachable radiators mounted at one end of the tank. The total weight of a complete transformer, including oil, is 66 tons. A number of these transformers as illustrated in the frontispiece have been supplied to the U.S.S.R.

The Company is now building an outstanding example of a three-winding transformer for the U.S.S.R. Its general arrangement is shown in Fig. 6. Three single-phase units form a 31,500 kVA bank for connecting together three systems for service at 121 kV, 38.5 kV, and 10.5 kV normal operating pressures, respectively. The 121 kV and 38.5 kV windings are Star connected and the 10.5 kV winding is Delta connected. Each winding is designed for the full capacity of 31,500 kVA, and the loading may be in any combination provided that no winding is loaded beyond its capacity of 31,500 kVA. There is an important

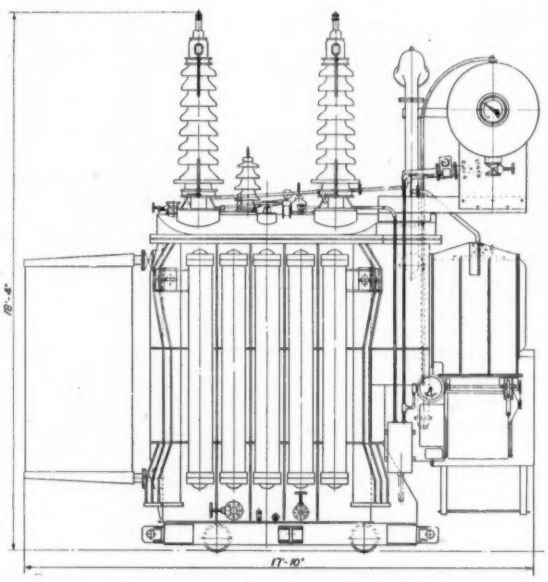

Fig. 6.—Single-phase Transformer for 31,500 kVA Three-phase Bank, 121/38.5/10.5 kV—Star/Star/Delta connected. On-load Tap-changing for 24% range on 38.5 kV.

feature in this transformer which adds to its complication in that tappings for on-load tap-changing are provided on the 38.5 kV winding for a range of plus and minus 12 per cent., giving 24 per cent. total range in fourteen steps. Also, on the 121 kV winding, tappings for plus and minus $2\frac{1}{2}$ per cent. and 5 per cent. variation about the normal voltage are provided and are connected to a tapping switch for off-circuit operation. The 38.5 kV winding is located next to the core ; the upper and lower halves are connected in parallel, the tapping coils being in the middle of each half. The 121 kV winding is on the outside and the tapping coils are in the middle of the column ; the 10.5 kV winding is located between the 121 kV and 38.5 kV windings and is suitably provided with gaps corresponding to tapping coils in the 121 kV and 38.5 kV windings, so that the resolved vertical mechanical forces under short-circuit conditions are well within the structure strength of the windings. With the wide range of tappings on the 38.5 kV winding, this problem is serious, and the special arrangement of windings, which is an important feature of all " English Electric " Transformers, is of the utmost value in producing the greatest possible mechanical strength to withstand conditions that will arise in service.

Discharge Regulators for the Argentine.

An Example of Local Manufacture.

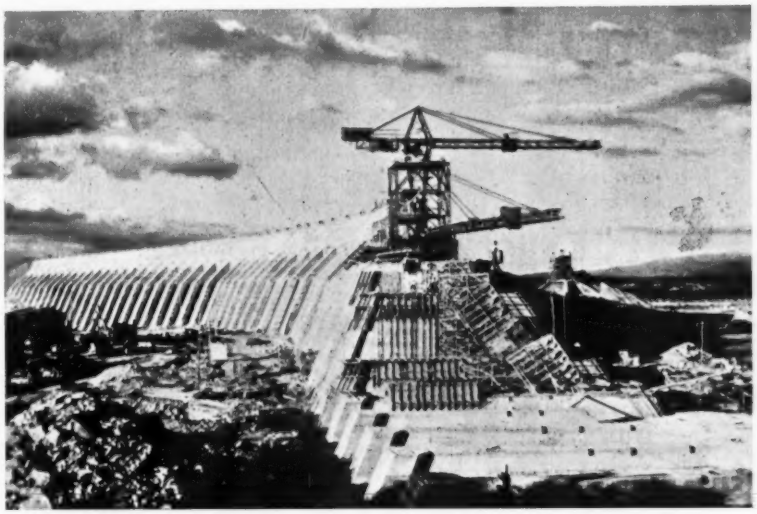

Fig. 1.—Cruz del Eje Dam, Ram's Head section, in course of construction.

The cylindrical balanced streamline discharge regulator is one of the most successful hydraulic products of the Company and many of them are operating in different parts of the world in connection with hydro-electric developments, irrigation works or wherever it is required to regulate the flow of water. The design and construction of the regulator and its many advantages were fully described in an article published in the Journal in December, 1941, and the present notes are confined mainly to a description of a batch of six regulators manufactured recently in the Argentine to the Company's designs.

It may not, however, be out of place briefly to refer to the action of the regulator. It consists of two concentric cylinders and a streamline dispersing cone which is attached to the inner cylinder by radial webs. The outer cylinder or piston slides on the inner cylinder and closes the space between the latter and the cone.

When open the water is diverted by the streamlined dispersing member and is automatically discharged in the form of a hollow divergent cone spreading over a rapidly increasing area which, furthermore, can be regulated according to local requirements. Thus its effective energy is quickly dissipated by air friction and

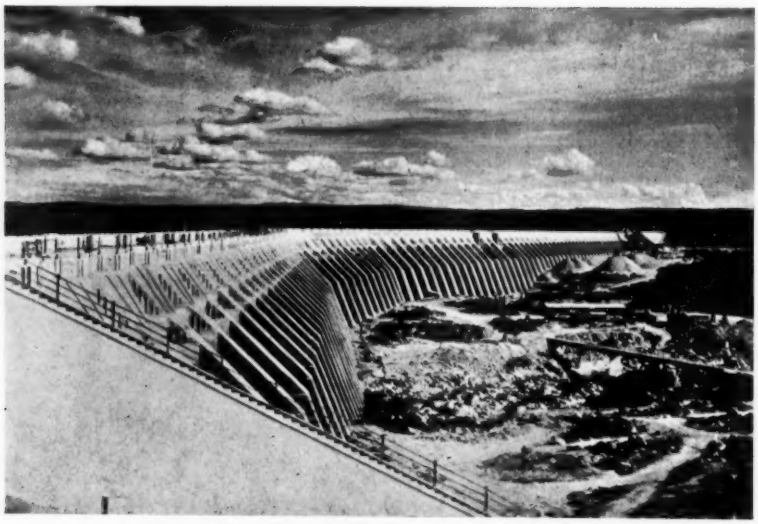

Fig. 2.—Cruz del Eje Dam, downstream side.

disintegration and the whole of the discharged water descends harmlessly in the form of a heavy shower.

Owing to the outstanding simplicity of its design and operation the discharge regulator is well suited to local manufacture and for some years past this procedure has been adopted in Australia and there are several examples of locally made regulators operating successfully in that country. This policy also conforms with the steady process of industrialisation which is taking place in many countries and makes the Company's hydraulic products more widely known; this cannot fail to have beneficial results in the approaching vast expansion of hydro-electric development throughout the world.

When, therefore, in the early part of last year the Company's Agents in Buenos Aires, Messrs. Evans Thornton & Cia., suggested that the manufacture of six discharge regulators ordered by the Cordoba Government Irrigation Department should be undertaken locally and produced satisfactory evidence that workshops suitable for the purpose were available, their proposal was confidently accepted and the necessary design and workshop drawings were put in hand.

The regulators were required for use in three separate dams in the Province of Cordoba and the requirements were briefly as follows :—

Dam.	San Roque.	La Vina.	Cruz del Eje.
No. of regulators ...	2	2	2
Diameter	5′ 0″	3′ 7″	3′ 7″
Maximum operating head	98′ 0″	184′ 0″	98′ 0″
Discharge, cubic feet per second ...	1,100	780	600
Minimum operating head	10′ 0″	26′ 0″	26′ 0″
Discharge, cubic feet per second ...	350	420	280

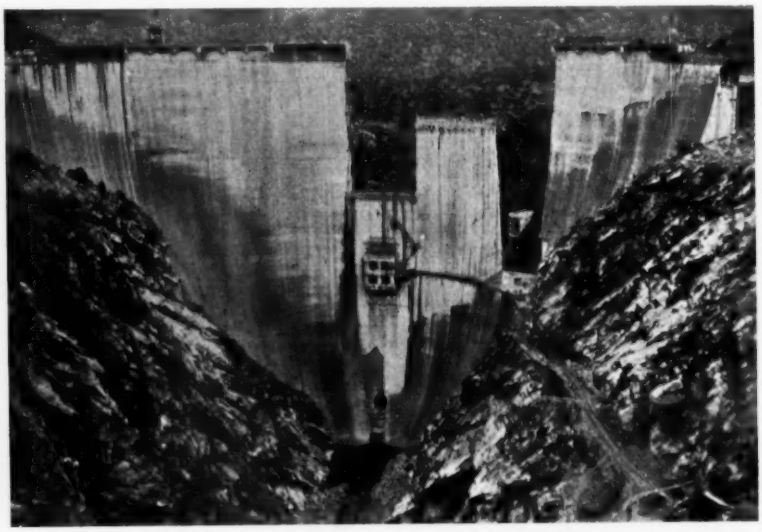

Fig. 3.—La Vina Dam, downstream side, showing valve house.

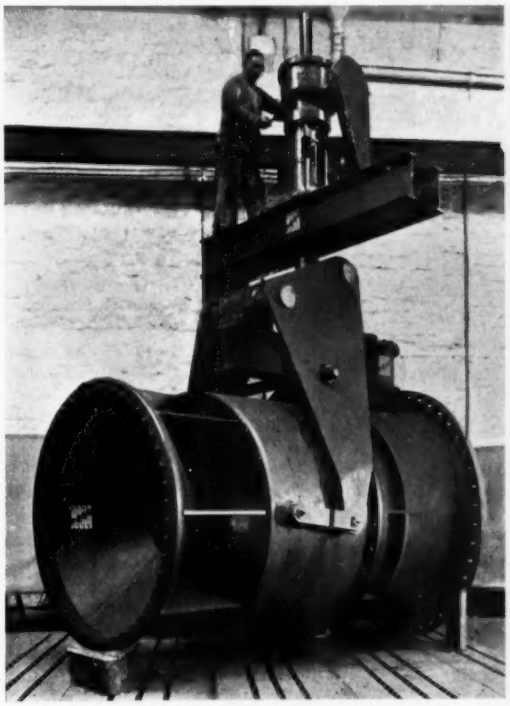

Fig. 4.—Discharge Regulator with reduction cone, for San Roque Dam.

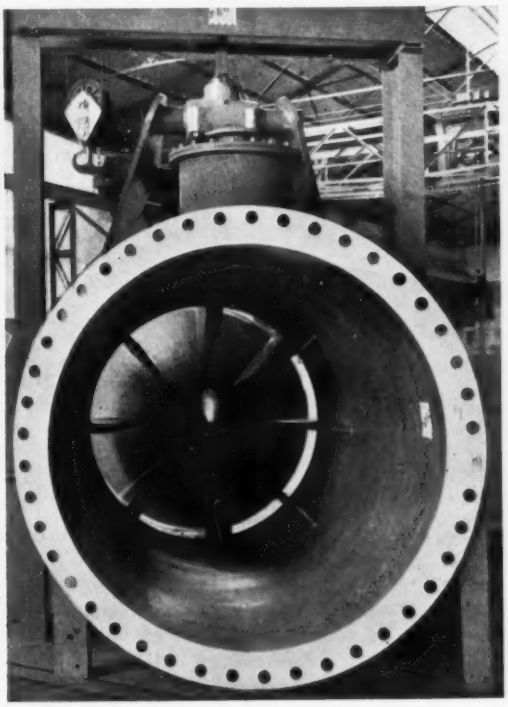

Fig. 5.—The Discharge Regulator shown in Fig. 4, viewed from upstream end.

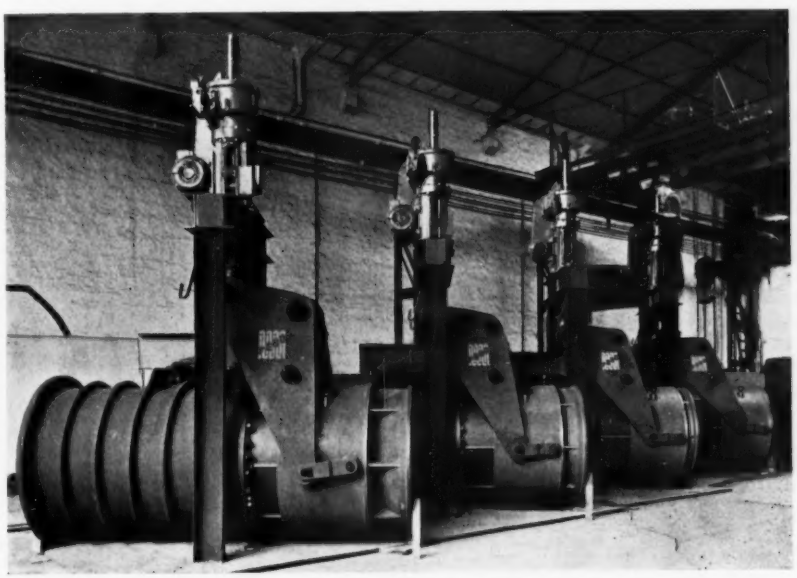

Fig. 6.—Four 3' 7" diameter Discharge Regulators, fully assembled.

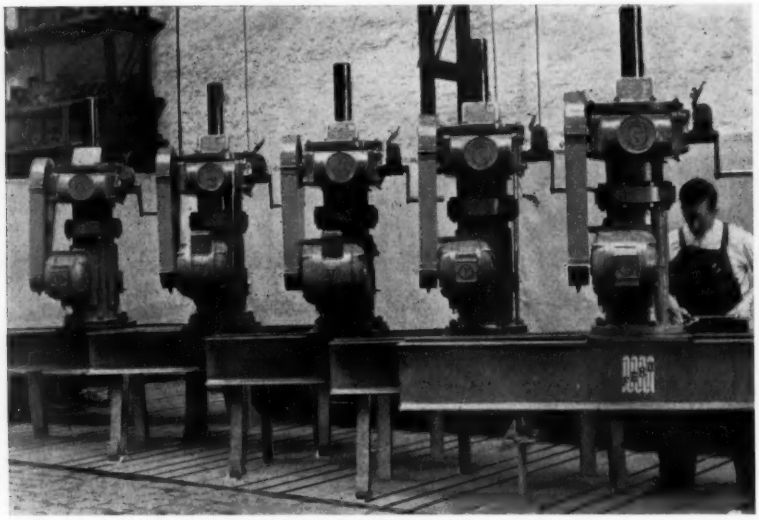

Fig. 7.—Motor-driven operating headstocks for Discharge Regulators.

Owing to the similarity of the hydraulic conditions it was found possible and economical to adopt the same regulator for La Vina and Cruz del Eje.

The regulators were made in the workshops of Messrs. Fischbach Enquin y Sidler, usually known as FEBO, who are very well-known in Buenos Aires and experienced in heavy fabricated work and electric welding. All detailed drawings and instructions were sent out from this country and the work was carried out under the supervision of the Company's Technical Representative with Messrs. Evans, Thornton & Cia. The regulators are of the usual construction consisting of inner body, piston, connecting gear and handgear column. In addition to the handgear, provision was made for operation by remote control by means of an electric motor and reduction gearing.

It is the usual practice to make the piston and seating ring of stainless steel but, owing to the difficulty of obtaining this material locally, it was decided to make the piston in gunmetal. The inner body was fabricated from mild steel plate, 1 in. and $\frac{7}{8}$ in. thick for the 5 ft. dia. and 3 ft. 7 in. dia. regulators respectively. After fabrication the inner bodies were carefully annealed. The regulators were completely assembled at the Works, the larger ones being tested for 24 hours at a pressure of 80 lbs. per square inch and the smaller at 143 lbs. per square inch, these pressures being equivalent to 1.75 times the maximum static head.

These tests were most successful and the sealing rings, consisting of vulcanised rubber packing obtained locally, were completely drop tight.

For testing the discharge capacity, a model of the 5 ft. regulator was built by the manufacturers to a scale of 1 : 10.

It is of interest to note that the projects for the three Dams in question, as well as their actual execution, were the work of three eminent Argentine civil engineers. The San Roque Dam is the work of Engineer Rodolfo E. Ballester; La Vina was undertaken by Engineer Santiago Fitz-Simon, while Engineer B. A. Reolin was responsible for the Cruz del Eje Dam. The manufacture of the discharge regulators for these Dams in Buenos Aires, therefore, fulfils a national aspiration.

Messrs. Evans, Thornton & Cia. are to be

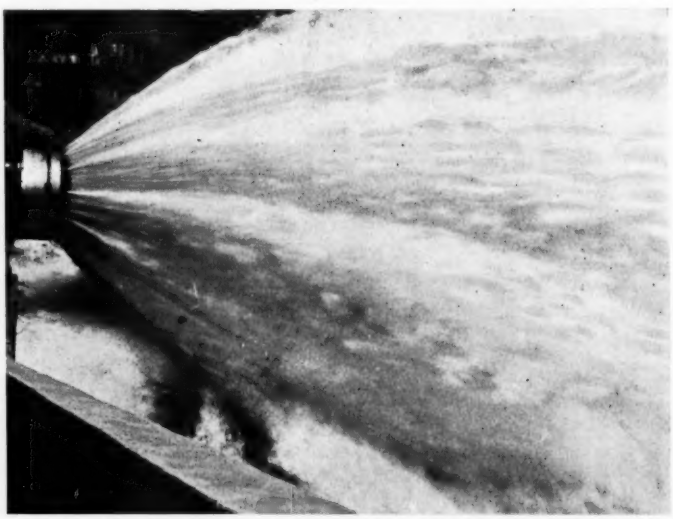

Fig. 8.—A Discharge Regulator of a similar type to those described, in action.

congratulated for their handling of this contract, and we are indebted to them for the photographs published with this article. Figs. 1 and 2 show the Cruz del Eje Dam, and Fig. 3 the La Vina Dam, under construction. The latter shows the opening in the dam face for the discharge regulator. Figs. 4 and 5 show the 5 ft. regulator assembled in the workshops. The central cone is shown clearly in Fig. 4, and a good impression is conveyed by Fig. 5 of the stream-lining with the inside ribs. The four 3 ft. 7 in. regulators in positions from full open to closed are shown in Fig. 6. Fig. 7 shows a group of hand gear columns fitted with the additional reduction gears and electric motors. Fig. 8 shows a cylindrical balanced discharge regulator of this type in action.

Regenerative Dynamometers.

Successful Results from Equipment Recently Installed at a Napier Factory by The English Electric Co., Ltd.

Reprinted from "Aircraft Production," June, 1944.

Readers will recall the efforts of this journal to focus attention upon the power running to waste in aircraft-engine testing plant. It is with some satisfaction, therefore, that we are now able to record that regenerative dynamometer installations are successfully in operation in this country and that they have fully justified the confidence of their supporters both inside and outside the industry. One installation has now been in operation at one of the Napier factories for several months, and the experience gained would indicate that technicians are well satisfied with its operation. In the August, 1942, issue of *Aircraft Production* there was a description of a scheme developed by The English Electric Co., Ltd., who were responsible for the manufacture and installation of the equipment described here.

These electrical dynamometers, an example of which may be seen in Fig. 1, are of the swinging frame torque reaction direct-current type, the field system of which is supported in trunnion bearings, and a torque weighing mechanism is provided which is arranged to give remote indication of the torque. Fig. 2 shows the indicator for the torque weighing mechanism and also the control desk.

A complication which has been satisfactorily dealt with arises from the possible future need for testing engines fitted with reduction gears for contra-rotation airscrews. This requirement involves an engine gear box with two concentric airscrew shafts, and obviously there must be two

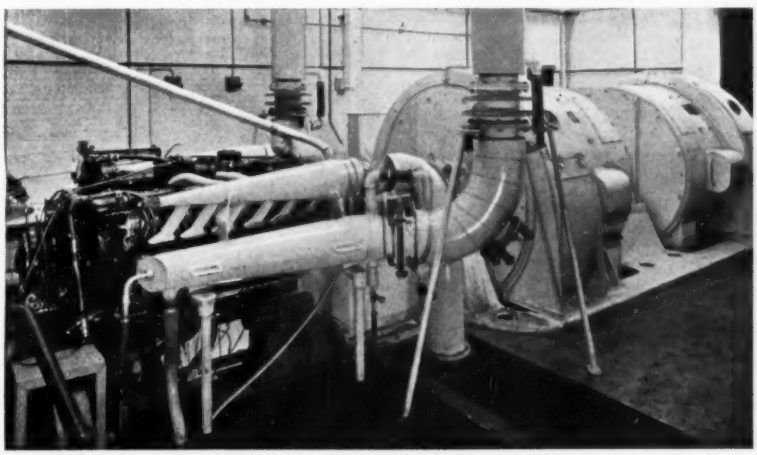

Fig. 1.—A Sabre engine in position on a swinging-frame torque reaction direct-current type electrical dynamometer built and installed by The English Electric Company.

similar shafts at the driving end of the dynamometer. The dynamometer, must, therefore consist of two units as seen in Fig. 1, the inner unit adjacent to the engine, having a hollow shaft through which an inner shaft is led and coupled to the solid shaft of the outer dynamometer.

In these circumstances, the two armatures of the dynamometer revolve in opposite directions, but it is a simple matter to reverse the connections of one of them to permit the testing of engines with single airscrew reduction gears. Clearly the couplings between the engine and dynamometer must be specially designed to meet these conditions, and changing from single-rotation to contra-rotation engines necessitates changing part of the coupling. The installations now in service, however, are provided with couplings specially designed to facilitate changeover from one type to the other.

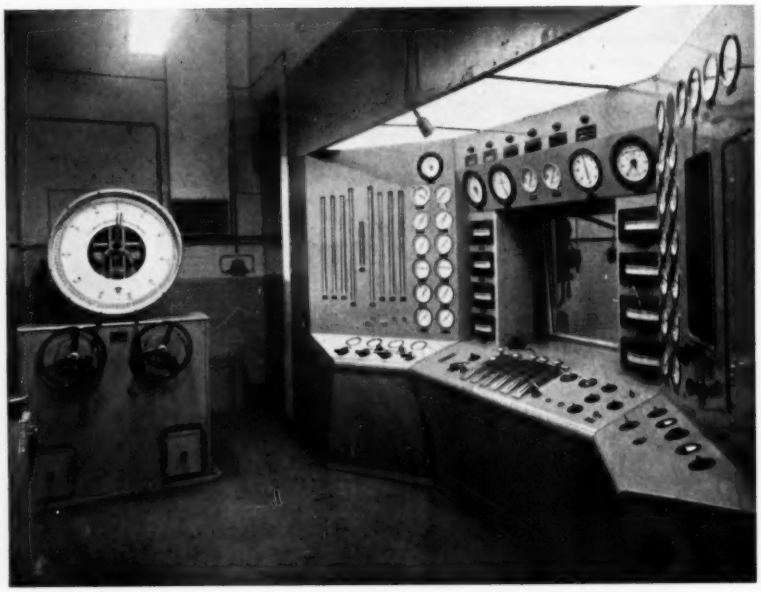

Fig. 2.—The control desk and (left) torque weighing indicator for the regenerative dynamometer installation.

Torque Weighing Gear.

The torque weighing gear, which is designed and constructed by Ashworth Ross & Co., Ltd., in conjunction with The English Electric Co., Ltd., is arranged to measure the individual torque of each unit of the dynamometer, and facilities are provided so that the torque of each unit can be varied to represent a difference in the airscrews.

To convert the power generated by the direct-current dynamometers into a form suitable for regeneration into the alternating-current supply system, The English Electric Co. have adopted the well-known Ward-Leonard system : this involves the use of a motor-generator set consisting of a synchronous alternating-current machine and two direct-current machines, each of which is coupled electrically to one unit of the dynamometer (Fig. 3). For driving the engine under test for starting, running-in or investigation of friction losses, the direct-current machines of the motor generator set are excited to give a voltage slightly in excess of that of the direct-current dynamometer. The latter will, therefore, function as a motor drawing power through the motor-generator set from the alternating-current system.

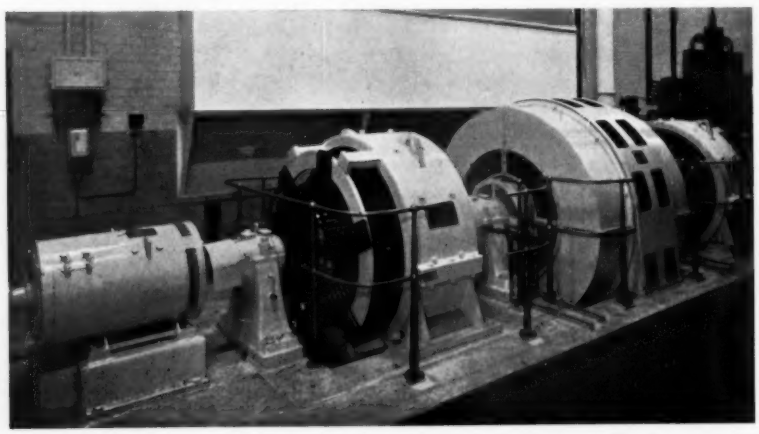

Fig. 3.—The motor-generator set, comprising two direct-current and one synchronous alternating-current machines, each coupled electrically to one unit of the dynamometer.

Conversely, when the engine is firing the excitation is so arranged that power flows from the dynamometer to the motor-generator set and thence to the mains. By suitably controlling the excitation any load and speed within the capacity of the plant can be obtained.

Ward-Leonard System.

The use of the Ward-Leonard system is not new in engine testing ; it has been employed by The English Electric Co. for testing engines other than aircraft types for a considerable number of years, and also has a wide application in other industries. By adopting this principle for aircraft engine testing the company claim that they are adopting a principle which has been well tried out and of which they have had considerable experience.

Experience obtained with the new regenerative equipment shows that the concern expressed by some critics on behalf of the power companies that the resulting series of peak loads would be objectionable has been unfounded. In any case, the peaks to be dealt with in engine testing are not so severe as those in other heavy industries and, moreover, it is not the peaks in kilowatts which matter to the supply system so much as their effect on the supply voltage. In this connection the plants in operation have provided clear evidence that even during acceleration tests a recording voltmeter connected to the A.C. mains shows no appreciable effect on the voltage. This instrument has been under observation by test engineers from well-known engine manufacturers, and all agree that the effect of the acceleration tests was well within the normal fluctuations of the supply voltage. Engineers from the power company have also expressed themselves as satisfied on this point.

Fig. 4 shows a section of the charts of a recording voltmeter and wattmeter, and the effect on the voltage during an acceleration test is seen to be negligible.

Another important aspect of this question is that supply authorities are not usually averse to the installation of plant which gives a measure of power factor correction, and the regenerative test equipments in use are designed with that object in view.

It is recognised that the first cost of fully regenerative equipment is higher than that of the power-dissipating type of brake ; it is also higher than that of the partially regenerative equipment, but not to the same extent. The latter, however, imposes limitations on the test facilities, and it is for the industry to say whether they are prepared to accept these limitations. In this respect reference to what is done in other countries is not the answer to the question. In any case, the recovery of power is greater with the fully regenerative scheme, and the additional facilities

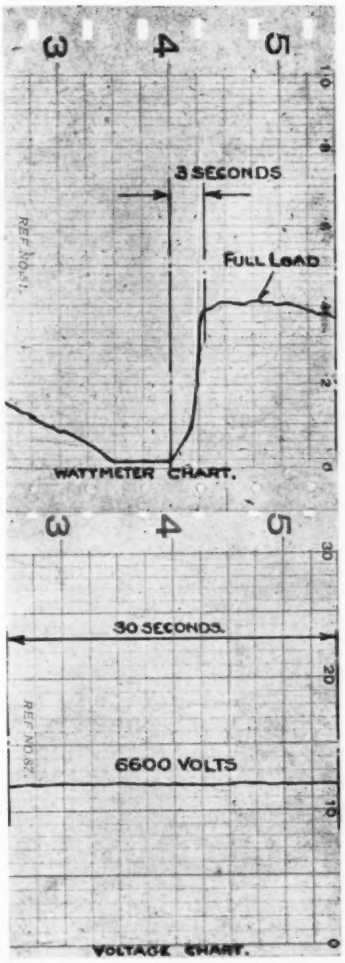

Fig 4.—Sections of charts made by a recording wattmeter (top) and voltmeter (bottom) showing that the effect on the voltage during acceleration tests is negligible.

available have the definite effect of reducing the time taken in testing, and thus in themselves have the effect of saving fuel.

Considerable emphasis has been laid on the alleged complications of the fully regenerative scheme when compared with others. Such criticism is perhaps inevitable with any new device, but other industries have in daily use similar electrical equipment without which their present progressive position would not have been achieved, and it is likely that engine-testing will eventually be placed in the same category.

To draw attention, therefore, to the number of rotating auxiliaries required by the fully regenerative plant is to lose sight of the advantages

obtained with that type. In any case, rotating auxiliaries are necessary with the heat-dissipating type of brake as motor-driven pumps and fans are required for the cooling plant. Moreover, to obtain the desired characteristics with any type of electrical dynamometer, whether fully regenerative or partially regenerative, auxiliary electrical equipment is required.

Electronic Control.

Attention has been drawn recently to the use of electronic control for obtaining the desired characteristics, but this system of control is merely a method of obtaining controlled excitation, just as is the use of rotating exciters; electronic control, therefore, is not peculiar to any particular type of dynamometer. The maintenance of rotating auxiliaries is within the capacity of any competent works electrician, whereas few maintenance staffs have yet been trained in the fault detection of thermionic valves and their associated equipment. The introduction of a small unit of this specialised nature may be troublesome on this account until such time as electronic devices are in more general use.

Summarising, the advantages claimed for the Ward-Leonard scheme are as follows :—

(1) Extreme flexibility of speed and load control.

(2) Ability to operate load and speed controls manually or automatically, manual control being available even with the controls set for automatic operation.

(3) Ability to bring the engine and dynamometer to rest quickly by means of electrical braking.

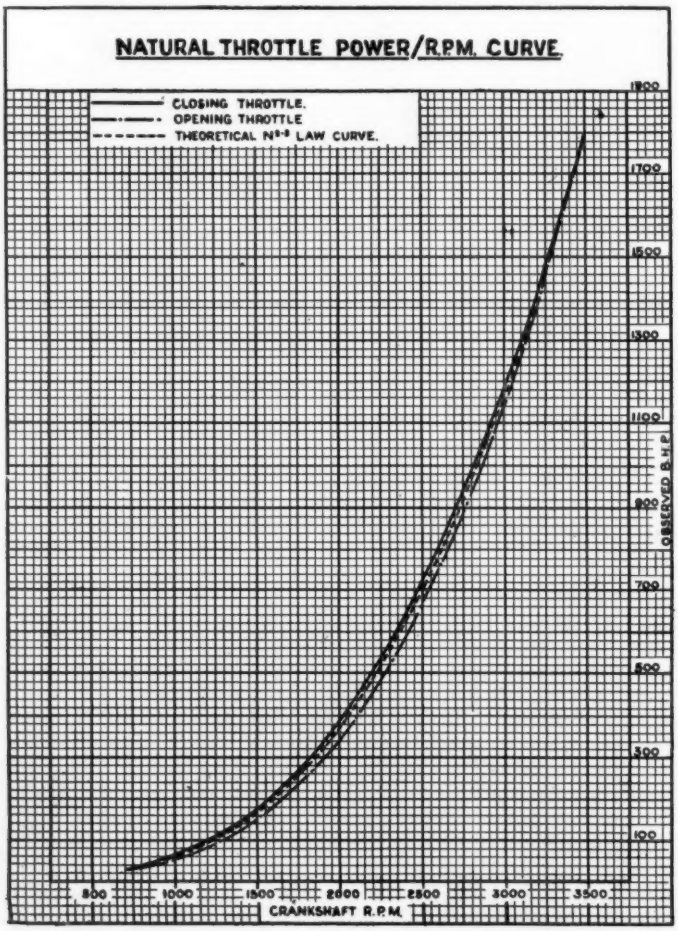

Fig. 5.—A throttle power/r.p.m. curve taken during an official acceptance test. Note that it lies extremely closely to the theoretical 2.8 law curve.

(4) Complete stability, particularly at low speeds and low loads. In this connection experience shows that facilities are available with these installations which enable tests such as weak mixture tests, which it has not been possible, or possible only with difficulty, to make on the earlier form of brake.

(5) In view of the absence of wearing parts the equipment retains its high degree of accuracy over its life.

(6) The motoring condition with motoring torque measurement is always available, thus enabling friction losses to be taken.

(7) Regeneration is available down to idling speeds, and at all times when the engine is firing.

(8) Ability to provide the following tests :—

(*a*) Throttle curve to match a fixed pitch propeller power/speed law without adjustment. Fig. 5 shows the curve taken during the official acceptance test and it will be noted that the actual curve obtained lies extremely closely to the theoretical 2.8 law curve. This curve was obtained without any adjustment of the controls other than to the throttle.

(*b*) Acceleration test with compensation for difference in inertia between dynamometer and airscrew, such compensation being adjustable.

(*c*) Constant speed maintained automatically under

variable load conditions such as obtain with variable boost, variable depression, or when making fuel consumption and ignition tests.

(*d*) Constant boost tests with correct automatic adjustment of load and speed.

(*e*) Variation of power between the two units of the dynamometer when testing contra-rotation engines to represent a difference in the airscrews, the equipment being designed so that power on any one of the two units can be reduced. Other facilities, details of which cannot yet be released, are also available.

With regard to the amount of power regenerated the figures available indicate that on some days over 8,000 units of electricity are being put back into the supply mains, but the average is, naturally, less than this. The figures indicate, however, than an annual recovery of over one million units will be obtained, and the value of this amount of power is ample justification that the installation is economically sound. A figure of one million units represents a saving from one plant alone of approximately 850 tons of coal per annum at present-day figures.

Unit Research Rigs.

In addition to the full-scale testing rigs described above, The English Electric Co. have supplied special unit test rigs to enable research and experimental work on twin-cylinder Sabre units. Here, again, the Ward-Leonard system has been adopted; the dynamometers have a maximum operating speed of 5,000 r.p.m. and are of the torque reaction direct-current type.

In this instance, however, the two dynamometers regenerate through a common motor-generator set which comprises two D.C. machines, one for each dynamometer, and a single alternating-current machine, the latter being designed to regenerate into the 400-volt A.C. supply. The torque weighing gear is mounted direct on the dynamometer bedplate.

The motoring facility with friction loss measurement is available with these rigs but the arrangements for obtaining the special characteristics described above for the full-scale engine are not necessary.

Amongst other activities connected with engine testing, The English Electric Company have installed within recent years, or have in course of manufacture, a large number of aero-engine super-charging testing dynamometer equipments. In all cases the dynamometers are of the swinging-frame direct-current type with torque weighing gear.

Transformer Maintains Service After Severe Lightning Stroke.

In accordance with B.S. 171-1936, the insulation tests normally applied to power transformers are (*a*) an applied test at normal frequency of (2E+1) kV, between windings and earth, and (*b*) an induced test of twice the normal voltage at any appropriate frequency above normal in order that the exciting current shall not exceed a reasonable value. The fact that a transformer has satisfactorily passed such tests does not necessarily ensure that a severe lightning stroke in the vicinity of the transformer will not damage it electrically and mechanically. Only long experience of service conditions coupled with considerable research and a high degree of skill on the part of the designer, will result in the confidence that the operating engineer should have in transformers installed on his system.

Fig. 1 illustrates a notable example of service given by a transformer under the most exceptional conditions. It was installed near a power station on a platform and coupled to an overhead 11 kV. line. It was damaged during a very severe lightning storm, but continued to supply load for eighteen hours, during which time it was exposed to very heavy rain, before it was removed from the circuit. Although the bushings were shattered by the lightning stroke the leads from the line kept the pieces in position and it was when the leads were disconnected that the bushings collapsed into the positions shown in Fig. 1. The transformer was taken to a repair shop where it was dried out, provided with new bushings and tested, and on being found to be in perfect condition it was put back into service.

A transformer of the same type as the one mentioned above is shown in Fig. 2. An interesting feature of the construction is the double arcing-horn on the 11 kV. bushing. The creepage surface of the bushing is large and to reduce the flash-over voltage to a safe value an arcing-horn is provided. With a single gap there is always the risk that it may be shorted inadvertently, as for

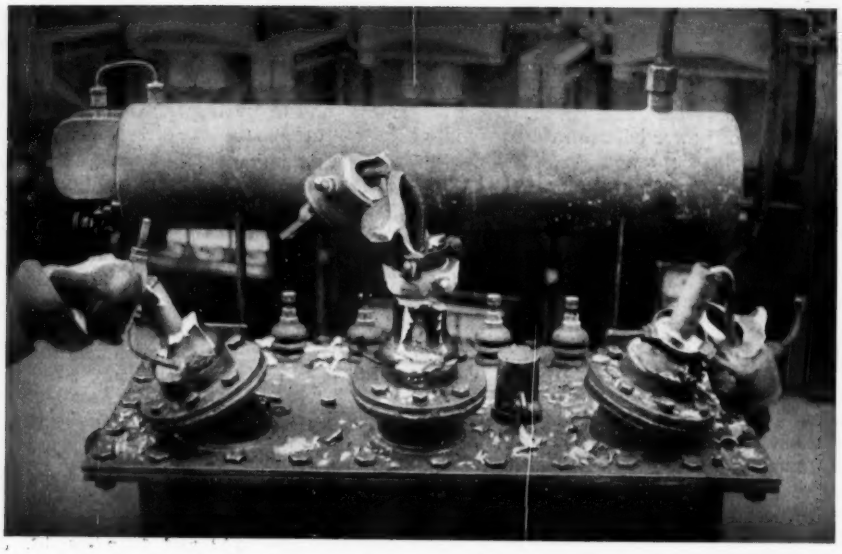

Fig. 1.—"English Electric" 11 kV Transformer showing damage after a severe lightning stroke; it continued to give uninterrupted supply until taken out of service for repairs eighteen hours later.

example, by a bird or twig, but with two gaps, displaced by about 120°, this possibility is negligible. This standard line of transformers is equipped with oil-conservators which should be universally adopted in the interests of maintenance of service.

LECTURES TO APPRENTICES AND STAFF PERSONNEL.

Lectures given to apprentices and staff personnel during the past six months included the following:—

2nd March—Dr. A. E. Dunstan, Director and Chief Chemist of the Anglo-Iranian Oil Company, one of the foremost authorities on petroleum, gave a lecture on petroleum which was followed by a film entitled "Oil Operations in Persia."

17th May—Mr. F. N. Sutherland, M.A., M.I.E.E., Managing Director of The English Electric Company of South Africa, and Mr. C. W. Goodman, B.E., M.I.E.E., M.I.C.Aust., General Manager in Australia for The English Electric Company, gave addresses on "The Career of the Technical Sales Engineer Abroad."

4th July—Mr. J. T. Moore, Manager of the Company's Steam Turbine Department, who recently visited the United States of America, gave a lecture on Steam Power Stations with particular reference to practice in Great Britain as compared with the U.S.A.

Fig. 2.—A typical "English Electric" 11 kV Distribution Transformer similar to the one illustrated in Fig. 1.